Relationship between diversity of forest plant and community dynamics in eastern mountain area of Heilongjiang Province, China

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Abstract: The biodiversity was studied in 26 communities with different structures in Maoershan National Park and Liangshui Natural Reserve of Northeast Forestry University in Heilongjiang Province, China. Composition index (CI) was taken as a parameter to quantify the community dynamics, which can nicely describe forest community dynamics, meanwhile, the relationship between diversity and community dynamics were also investigated and analyzed. Results showed that the total number species of community, richness, evenness, and Shannon-Wiener diversity index were obviously different in every community. The richness decreased with the increasing CI of every community, which means richness was in inverse proportion to community dynamics. The Shannon-Wiener index of every community increased from the initial stage to the middle stage of succession, and then decreased in the climax stage. The coverage weighted foliage-height diversity index increased along with the increase of CI, which was similar as the pattern diversity.

Key words: Eastern mountain area of Heilongjiang province; Shannon-wiener diversity; Pattern diversity; Community dynamics
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Introduction

Biodiversity is a popular way of describing the diversity of life on earth. It includes all life forms and the ecosystems in which they live (Menini 1998). Biodiversity plays a fundamental role in organic and sustainable food production, and ensures countless kinds of foods as well as raw materials for clothing, shelter, fertilizers, and medicines (Wang 2006). In agriculture, genetic diversity enables crops and animals to adapt to different environmental conditions. Biological resources are sustainable if they are not excessively exploited. People should be alarmed by the destruction of plant communities caused by cutting, burning, weeding, cleaning, over fertilizing, over watering, and pollution. Scientists estimate that there are about 1.4 millions species on earth, including 750 000 insects, 41 000 vertebrates, and 360 000 plants (Willson 1988). In the last thirty years, as the world population is increasing, the natural element supporting human existence is diminishing, about 35 000 plant species have disappeared (Lugo 1980; Menini 1998).

Conventional ecological theory suggests that diversity increases with time (Odum 1969). However, recent studies found that biodiversity of terrestrial arthropods in forest communities increases to a peak and then declines toward a stable climax community (Niemela 1996). Many studies on succession patterns mainly focused on plants and less mobile organisms (Timoney 1996; Whittle, *et al*. 1997). Without great dispersal abilities, such organisms are implicitly assumed to be members of a local community. As such, they likely reflect the successional state of that community. In contrast, more mobile taxa with larger cruising ranges than a local community tend to be excluded. In fact, a major problem associated with sampling wide-ranging taxa is that the trapped species may not necessarily represent actual community members (Niemela 1996; Rykkon *et al*. 1996). However, exclusion of such taxa from ecological monitoring programs neglects potentially the most taxonomically abundant and diverse organisms in an area. Therefore, these organisms could best reflect ecological status of a community.

Any forest community is in a specified succession stage, if you want to discover the relationship between community dynamics and diversity, quantifying the succession of forest community is the most important. In the present study, we used the Compositional Index (CI) given by Curtis & McIntosh (1951) to quantify the succession of forest community. The relationship between diversity of forest plant and community dynamics were studied, and the diversity was described by species diversity given by Magurran (1988) and community structure diversity, which was divided into horizontal and vertical structure, horizontal structure diversity was calculated by pattern diversity given by Pielou (1966), and vertical structure diversity was calculated by coverage weighed foliage-height diversity index given by MacArther (1955).

Study site

The study sites were separately chosen in Liangshui Natural Reserve (128°48′–128°55′E, 47°07′–47°14′N) and Maoershan National Park (127°30′E–127°34, 45°20′–45°25′N) of Northeast Forestry University, China. In total of 26 forest communities were selected, of which, 23 are secondary forest communities in Maoershan National Park, and 3 are virgin Korean pine forest communities in Liangshui Natural Reserve.

Quantification of community dynamics

Community changes during succession include changes in diversity and composition of species. Thus, it is very important that how to quantify the community stage, which means how far to

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the climax for any community. As we know, there is a fixed climax community in any region. For example, in Northeast China, the broadleaved Korean pine forest is the climax community (Heilongjiang Forest Editor Committee 1993). For exploring the relationship between the diversity and community dynamics, the most program is how to quantify the community dynamics.

Curtis & McIntosh (1951) put forward a method, compositional index (CI), to quantify the community dynamics. The value of CI equals importance value (IV) (Every tree species in the community) multiplied by climax adaptation number (CAN), the equation is as follows:

$$CI = \sum IV \cdot CAN \quad (1)$$

According to the above equation, the value of CI can be calculated. There is different CAN value in different region, and the CAN value ranges from 1 to 10. The values of CAN in eastern mountain area of Heilongjiang Province are listed in Table 1 given by Wang (2006). The value of CI of every community is listed in Table 2.

Table 1. The CAN of every important trees in Heilongjiang forestry area

Tree species	Climax adaptation number (CAN)
Pinus koraiensis	10
Abies nephrolepis	6.6
Acer mono	5.2
Picea koraiensis	4.7
Tilia amurensis	4.3
Betulla costata	3.9
Ulmus propinqua	3.8
Qurcus mongolica	3.0
Betulladavurica	2.7
Fraxinus mandshurica	2.4
Juglanss mandshurica	2.2
Phellodendron amurense	2.0
Larix gmelinii	1.5
Betulla platypfylla	1.2
Populus davidiana	1.2

Table 2. The value of CI for every community

Plot No.	CI	Plot No.	CI	Plot No.	CI
1	3.17	10	3.12	19	3.13
2	0.00	11	4.15	20	4.45
3	3.96	12	3.67	21	3.33
4	4.89	13	3.02	22	5.07
5	4.03	14	3.27	23	2.32
6	4.06	15	5.66	24	6.23
7	2.80	16	3.21	25	7.32
8	4.05	17	3.68	26	6.46
9	3.82	18	3.49		

Data collection

In each plot (20 m×20 m), the number of species, the number of individuals for every species, grass coverage, tree height, altitude of plot, slope gradient, exposure, slope position, soil depth, and soil moisture were investigated.

Measurement of diversity

Species diversity

The species diversity was calculated by the following four indices, the total number of species in community (N), evenness (E), richness (λ), and Shannon-Wiener *(H')*. The equations for these indices are as follows:

$$H' = -\sum P_i \ln P_i \quad (2)$$

where, H' is the value of the Shannon-Wiener diversity index, P_i is the proportion of the *i*th species.

$$\lambda = N(n-1) / \sum n_i(n_i - 1) \quad (3)$$

where, N is the total number of species in the community, n_i is the number of the *i*th species.

$$E = H' / \ln s \quad (4)$$

where, H' is the actual H', ln*s* is the maximal H'.

Structure diversity

Pattern diversity

Considering a collection consisting of a community of sessile organisms, for instance all the plants grow in a defined area, we measured not only the species diversity of the whole community but also that of groups of neighboring individuals within it. If the individuals of the various species are randomly mingled or unsegregated, any group of *n* neighboring individuals is equivalent to a simple random sample of size *n* drown from the whole population. The expect value of H for a simple random sample can be calculated as will be shown below. Let this expectation be denoted by $E[H(n)]$.

Supposed, now, a rule is specified for selecting group of neighboring individuals: for instance one might take the nearest individual to the center in each of *n* sectors centered on a random point. For each observed group of *n* neighbors one may calculate its observed species-diversity ($H_{(n)}$), and by repeated sampling to obtain the mean ($\overline{H}_{(n)}$), for a large sample of such groups. Then, if the individuals in the population are randomly mingled, $\overline{H}_{(n)}$ has not a significant difference with $E[H(n)]$.

It will often be found natural communities that $\overline{H}_{(n)}$ is significantly less than $E[H(n)]$. This phenomenon will happen if the species exhibit some degree of segregation so that there is a tendency for them to occur in relatively pure single species clumps. The species-diversity of a group of *n* neighbors will then be less than that of a simple random sample of size *n* drawn from the whole population. When this occurs we can conclude that the pattern-diversity of the community is low, in other words, the species-diversity in small sub-areas within the whole area is less than that would be expected in an unsegregated community. A convenient measure of pattern-diversity is given by the ratio:

$$D = H(n) / E[H(n)] \quad (5)$$

The Eq. 5 can be simplified in the equivalent form $B(n) / E[B(n)]$, where $B(n) = n \cdot H(n)$ denotes the

total information content per group of n individuals.

The pattern-diversity of the population is measured as follows. On the original map of each plot a number of random points were placed by means of random coordinates. For 26 plots, 100 points were used. At each point the nearest tree in each of three non-overlapping 120° sectors centered on the point was observed; the species composition of each such "triplet", or group of tree neighboring trees, was recorded.

The mean information content per triplet is

$$B = 1/M \cdot \sum M_i B_i \tag{6}$$

where $M = \sum M_i$

The expected information content in random samples of size from the whole population is

$$E(B) = \sum q_i B_i \tag{7}$$

where the q_i is calculated from data on the species composition of the whole population as follows:

With probability

$$\sum N_i^{(3)} / N^{(3)} = q1 \tag{8}$$

When all three individuals belong to the same species, giving B(3)=0 bits.

With probability

$$N_i^{(2)} N_j / N^{(3)} = q2 \tag{9}$$

When two individuals belong to one species and one individual belong to the other species, giving

$$B(3) = \log_2^{(3!/2!1!)} = \log_2^{3} = 1.58496 \text{ bits}$$

With probability

$$\sum 6 N_i N_j N_k / N^{(3)} = q3 \tag{10}$$

When all three individuals belong to different species, giving

$$B(3) = \log_2^{(3!/1!1!1!)} = \log_2^{6} = 2.58496 \text{ bits}$$

Then

$$D = B / E(B) \tag{11}$$

Vertical structure diversity

The vertical structure diversity is calculated by coverage weighted foliage-height diversity index, and the equation is as follows:

$$H_c' = -\sum (C_i / C \cdot H_i / H) \ln(C_i / C \cdot H_i / H) \tag{12}$$

Where, Hc' is the coverage weighted foliage-height diversity index, C_i the coverage of the ith foliage-height, C the total coverage of community, H_i the height of ith foliage-height, and H is total height of community.

Results

Diversity of every community

The total number species of community (N), richness (λ), evenness (E), Shannon-Wiener diversity index (H'), pattern diversity index (D) and the coverage weighted foliage-height diversity index (Hc') are calculated (Table 3). Results showed that N, λ, E, H', D and Hc' were obviously different in every community.

Relationship between diversity and community dynamics

The richness decreases with the increasing CI of every community (Table 3 and Fig.1), which means richness is in inverse proportion to community dynamics. The reason is that the richness species are not more and more significant with the community approaching to the climax. In a climax community, there is one species existing significantly, however, all the species are living evenly in all community.

Table 3. The values of N, λ, H', E, D, Hc' for every community

Plot No.	N	λ	H'	E	D	Hc'
1	56	0.079	3.06	0.760	0.475	0.755
2	94	0.044	3.05	0.805	0.185	0.206
3	65	0.054	3.50	0.840	0.341	1.021
4	108	0.060	3.66	0.780	0.537	0.797
5	74	0.062	3.31	0.769	0.664	0.910
6	62	0.063	3.25	0.786	0.185	0.874
7	39	0.378	1.77	0.484	0.000	0.327
8	62	0.054	3.35	0.811	0.698	1.083
9	53	0.072	3.13	0.788	0.520	0.876
10	73	0.076	3.27	0.760	0.304	0.885
11	55	0.057	3.30	0.824	0.509	1.002
12	83	0.080	3.27	0.740	0.404	1.054
13	59	0.078	3.12	0.766	0.113	0.832
14	70	0.215	3.65	0.623	0.411	0.921
15	78	0.046	3.52	0.807	0.120	1.342
16	67	0.111	2.91	0.691	0.515	1.055
17	68	0.093	2.86	0.677	0.186	1.258
18	42	0.149	2.50	0.670	0.285	1.051
19	60	0.238	2.28	0.557	0.285	1.059
20	70	0.068	3.28	0.770	0.112	0.358
21	70	0.069	3.10	0.720	0.286	0.921
22	94	0.047	3.51	0.770	0.432	0.857
23	78	0.150	2.80	0.650	0.298	0.884
24	67	0.120	2.76	0.660	0.835	1.121
25	88	0.050	3.40	0.820	0.879	1.120
26	63	0.075	3.22	0.760	0.804	1.164

The Shannon-Wiener index is low in early succession of community (Table 3 and Fig.2). With the increase of CI, the species diversity index increased rapidly and obviously, but decreased at the stage of nearing the community climax. The results showed that the species diversity index was highest at the stage of middle succession, and in the early and lately stage of community succession, the species diversity index was relative lower. Therefore, the Shannon-Wiener index of every community exhibited an increasing trend from the initial stage to the middle stage of succession, and then decreased in the climax stage.

The pattern diversity index increases along with the increase of CI (Table 3 and Fig.3), and the results indicated that the individuals of the various species were randomly mingled or unsegregated with the community approaching to the climax. In the early stage of community succession, the niches of species were overlapped, the interspecies or intraspecies competition was very strong, thus, the same species had chance to live together. With the community dynamics going on, eliminating occurs through

selection during long time competition, and the remanent species in community can live better in habitat. In a word, the pattern diversity continually increased from the initial stage to the climax.

The coverage weighted foliage-height diversity index increases along with the increase of CI, which was similar as the pattern diversity.

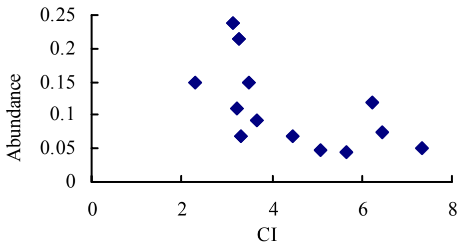

Fig.1 The relationship between H' and CI

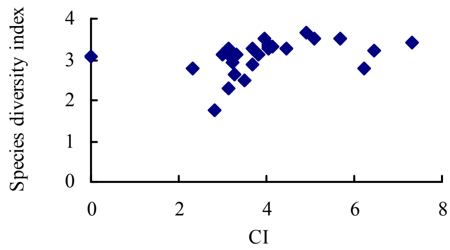

Fig.2 The relationship between λ and CI

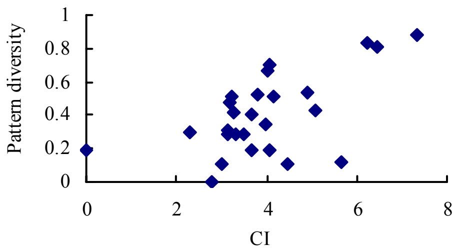

Fig.3 The relationship between D and CI

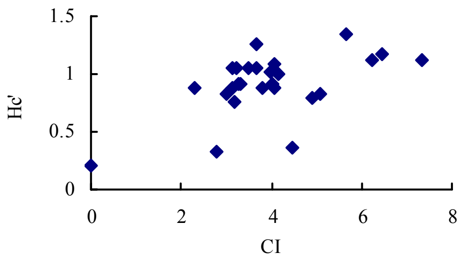

Fig.4 The relationship between Hc' and CI

Conclusion

Diversity can be described by species diversity and structure diversity. The species diversity can be divided into the total number species of community, richness, evenness, and Shannon-Wiener diversity index. The structure diversity can be divided into horizontal structure diversity and vertical structure diversity, which can be calculated by the pattern diversity and coverage weighed foliage-height diversity index, respectively.

The total number species of community, richness, evenness, and Shannon-Wiener diversity index were obviously different in 26 communities with different structures in Maoershan National Park and Liangshui Natural Reserve of Northeast Forestry University in Heilongjiang Province, China. The richness decreased with the increasing CI of every community, which shows that richness is in inverse proportion to community dynamics. The Shannon-Wiener index of every community increased from the initial stage to the middle stage of succession, and then decreased in the climax stage.

The coverage weighted foliage-height diversity index increased along with the increase of CI, which was similar as the pattern diversity.

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